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OIL AND GAS DEVELOPMENT IN VIRGINIA DURING 1976[1]

A total of 6,937,326 Mcf (thousand cubic feet) of natural gas was produced in Virginia during 1976, which is an increase of 214,489 Mcf from 1975 production. Reported production was from 180 wells in four counties: Buchanan County, 4,530,276 Mcf; Dickenson County, 1,489,129 Mcf; Tazewell County, 908,209 Mcf; and Wise County, 9,712 Mcf. Oil production in Lee County was 2,696 barrels from seven wells.

Eight new tests were drilled and three old wells were deepened. Columbia Gas Transmission Corporation drilled six of these holes in Buchanan, Dickenson, Scott, and Wise counties with combined footage of 31,669 feet. Three wells were completed with a combined final open flow of 4,274 Mcf of gas, one hole was waiting on fracture, and two tests were plugged and abandoned as dry holes. No new tests were drilled by Philadelphia Oil Company but they deepened three wells in Dickenson County. Lee Oil Drilling Company drilled one exploratory hole in Lee County. Westinghouse Electric Corporation drilled one exploratory hole in Washington County. Total footage drilled during 1976 was 43,454 feet, including 2,332 feet of deeper drilled footage.

Four operators in Buchanan County produced 4,530,276 Mcf of gas: Ashland Oil, Inc., 473,207 Mcf; Cabot Corporation, 24,349 Mcf; Columbia Gas Transmission Corporation, 3,986,577 Mcf; and P & S Oil and Gas Corporation, 46,143 Mcf. Two wells were drilled in Buchanan County by Columbia Gas Transmission Corporation with the final open flow for one as 2,716 Mcf; the other is awaiting fracture. Footage drilled totaled 9,065 feet.

In Dickenson County the Clinchfield Coal Company delivered 235,716 Mcf of gas to the pipelines of Kentucky-West Virginia Gas Company. Columbia Gas Transmission Corporation produced 1,253,413 Mcf to give Dickenson County a total production of 1,489,129 Mcf. Two holes were drilled in Dickenson County by the Columbia Gas Transmission Corporation with a final open flow for one as 1,205 Mcf; the other was plugged and abandoned. Three wells were deepened by Philadelphia Oil Company for a total of 2,332 feet with a combined final open flow of 498 Mcf; one well was yet to be cleaned out. Total footage drilled in the five holes was 16,058 feet.

In Lee County oil production by Robert F. Spear and Lee Oil Drilling Company totaled 2,696 barrels. Robert F. Spear produced 2,524 barrels from five wells in the Rose Hill field and one in the Ben Hur field. Lee Oil Drilling Company produced 172 barrels from one well in the Rose Hill field. Lee Oil Drilling Company drilled one test to a depth of 3,998 feet; it was plugged and abandoned as a dry hole.

In Russell County there was no gas production as Clinchfield Coal Company discontinued the use of gas from two wells formerly utilized in the now inactive Carbo Lightweight Aggregate plant. Gulf Oil Corpora-

[1] Information supplied by William W. Kelly, Jr., Virginia Division of Mines and Quarries.

tion commenced drilling an exploratory test in Russell County to the north-northwest of Dickensonville.

Columbia Gas Transmission Corporation drilled one development well to a depth of 4,278 feet in Scott County; final open flow was 353 Mcf of gas.

Two operators in Tazewell County produced 908,209 Mcf of gas: Columbia Gas Transmission Corporation, 314,667 Mcf and Consol-Ray Resources, 593,542 Mcf.

Westinghouse Electric Corporation finished drilling an exploratory gas test in Washington County southwest of Saltville. It was drilled to a depth of 5,455 feet and plugged and abandoned as a dry hole.

In Wise County Penn Virginia Corporation produced 9,712 Mcf of gas for use in a coal preparation plant. Columbia Gas Transmission Corporation drilled one test to a total depth of 4,600 feet; it was plugged and abandoned as a dry hole.

Table 1.—Summary of Virginia drilling during 1976.

Operator	Lease	Well No.	Total Depth (feet)	Status
Buchanan County				
Columbia Gas Transmission Corporation	Josh Deel, et. al.	20006	4670	Gas well
"	Grover Deel	20342	4395	Will fracture
Dickenson County				
Columbia Gas Transmission Corporation	Bruce Mullins	20321-T	9361	Plugged and abandoned
"	Pittston Company	20341	4365	Gas well
Philadelphia Oil Company	Pittston Company	P-57	5552 (768 D.D.)	Gas well
Philadelphia Oil Company	Pittston Company	P-58	4830 (792 D.D.)	Gas well
Philadelphia Oil Company	Pittston Company	P-60	5092 (772 D.D.)	Cleaning up
Lee County				
Lee Oil Drilling Company	Wayne Burgan	1	3998	Plugged and abandoned
Scott County				
Columbia Gas Transmission Corporation	William B. Cohen	20252	4278	Gas well
Washington County				
Westinghouse Electric Corporation	Morton Salt Company	1	5455	Dry hole
Wise County				
Columbia Gas Transmission Corporation	Penn Virginia Corporation	20255	4600	Dry hole

TRACE ELEMENTS IN STREAM SEDIMENTS DERIVED FROM THE CATOCTIN FORMATION, NORTHERN VIRGINIA

Christopher R. Halladay

A stream-sediment geochemical study was made in part of the Blue Ridge province in northern Virginia primarily for the purpose of outlining areas likely to contain copper or other base-metal mineralization. Attempts were also made to relate the distribution of trace elements in stream sediments to recently mapped structural features and to identify interrelationships of elements that might aid in mineral exploration in similar rocks and terrain.

The study area, consisting of approximately 50 square miles (130 sq km), is northeast of and adjacent to a district that has been know as the "Blue Ridge copper belt" (Weed, 1911). More than 90 percent of the area is in the Ashby Gap and Linden quadrangles

(Figure 1). The remainder is in the Bluemont, Boyce, Flint Hill, and Upperville quadrangles. Parts of Clarke, Loudoun, Fauquier, Rappahannock, and Warren counties are included.

Ninety-three stream sediment samples were collected in October 1974 and analyzed for copper, zinc, cobalt, chromium, nickel, iron, and manganese. Detailed resampling of one stream, which contained anomalously high chromium and nickel, was done in June 1975.

GEOLOGY AND COPPER DEPOSITS

The effect of lithology on trace element concentrations was kept to a minimum by sampling stream sediments that were derived from only one rock-stratigraphic unit—the Catoctin Formation (Figure 1). The Catoctin is composed mainly of dark- to grayish-green, massive, amygdaloidal metabasalt and epidosite. The formation also contains minor thin beds of tuffaceous phyllite, epidotized quartzose metasedimentary rock, rhyolitic metatuff, and purple amygdaloidal slate (Gathright and Nystrom, 1974; Lukert and Nuckols, 1976). The formation is estimated to be 1,500-3,000 feet (458-914 m) thick and to have an outcrop width of approximately 2.7 miles (4.3 km).

By sampling only in an area underlain predominantly by metabasalt, fluctuations in background concentrations due to lithologic variation are reduced and the contrast between samples from mineralized and unmineralized zones should be enhanced. Dahlberg (1967, 1969) found that the differences between trace element values in stream sediments derived from metabasalt and those from other rock types was so large that the presence of copper workings within metabasalt could not be detected.

It is unlikely that significant variations of trace element values would be caused entirely by differences in the amount or distribution of unmineralized epidosite. The chemical data of Reed and Morgan (1971) show that trace element concentrations in the two rock types are not statistically different.

Copper mineralization in the Blue Ridge has been known since the region was first settled. Luttrell (1966) lists 18 abandoned native copper mines and prospects in the Catoctin Formation from Clarke County southwestward through Greene County. None have been active since the early 1900's. Except for one small prospect near Paris, all the reported occurrences are south of Linden. Three mines lie within the study area: the Sealoch, Ambler, and Manassas Gap mines (Figure 1). Descriptions of the geology and development of these properties are given by Watson (1907), Weed (1911), and Luttrell (1966). In general, the ore is in epidotized metabasalt and is associated with jointing or shear planes. Chalcopyrite, bornite, cuprite, malachite,

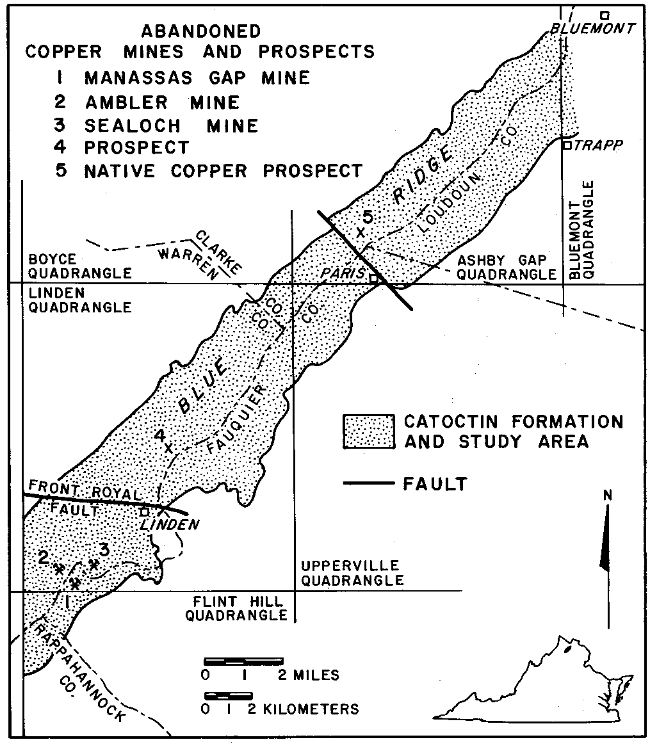

Figure 1. Index map showing location of the study area, Catoctin Formation, copper mines and prospects, counties, quadrangles, and the Blue Ridge.

and azurite have been reported in addition to native copper.

One prospect (location 4, Figure 1), not previously reported in the literature, is located about 2 miles (3 km) northeast of Linden on the property of Freezeland Orchards. Local residents say that this prospect has not been worked since the early part of the century.

Brophy (1960) reported several modes of occurrence of copper in the western belt of the Catoctin Formation: in magnetite and pyroxene in fresh flows and dikes, as chalcopyrite in probable feeder dikes, as disseminated native copper in some flows, and as native copper associated with quartz-serpentine veins in certain epidotized metabasalts. Brophy (1960), Weed (1911), and Allen (1966) noted that the redistribution and concentration of copper into fractured basalt is facilitated by epidotization and serpentinization during regional metamorphism.

ANALYTICAL METHODS AND RESULTS

Most of the streams sampled are first- or second-order, flowing either northwestward or southeastward down the flanks of the Blue Ridge. The average stream gradient is about 500 feet/mile (95 m/km). Sediment was collected within active stream channels, upstream from obvious sources of contamination. The samples were wet sieved in the streams to -10 mesh (2.0 mm) and later wet sieved to -80 + 230 mesh (0.063 to 0.177 mm) in the laboratory.

Ten ml of 3N HCl were added to 1.000 g of each sample and heated at approximately 70°C for 30 minutes. Then ten ml of distilled water were added and heating was continued for another 30 minutes. The liquid was decanted into volumetric flasks and diluted to 50 ml. Analysis for copper, zinc, cobalt, chromium, nickel, iron, and manganese was made using a Varian Techtron AA-4 atomic absorption spectrophotometer. Elements taken into solution by the HCl extraction were mostly those contained in iron-manganese oxide coatings on the sand grains. Most of the streams that were sampled are fast flowing and therefore of relatively high pH and Eh, which are conditions favorable to the inclusion of trace elements in oxide coatings.

Means, ranges, standard deviations, and relative standard deviations are shown in Table 1 for log-transformed and untransformed concentrations. Graphs of frequency distributions (histograms) showed that for most of the elements the concentrations were more normally distributed when expressed as logarithms. Log-transformed values were therefore used to calculate correlation coefficients.

Simple interelement correlation coefficients calculated for all pairs of elements (Table 2) reveal a high degree of correlation among most of those analyzed. The most significant correlations ($r > .80$) are between the pairs Cr-Ni, Cu-Co, Zn-Co, Cu-Ni, Co-Fe, and Co-Mn. The high coefficients between Co-Fe and Co-Mn are probably a reflection of the close association of Co with secondary Fe-Mn oxide coatings.

The three lowest coefficients are between Cr-Fe, Cr-Mn, and Ni-Fe. There is little difference between the correlations of Cu, Zn, and Co with Fe and with Mn; however, Ni and to a lesser extent Cr show a stronger association with Mn than with Fe.

In order to determine to what extent correlations among Cu, Zn, Co, Cr, and Ni are dependent on the effects of Fe and Mn, partial correlation coefficients were calculated (Table 2). These correlations essentially remove the influence of Fe or Mn, or both, on the relationships between two other variables. Most of the elements are intercorrelated even with the effects of Fe and Mn removed, although some coefficients are considerably reduced. Correlations between Zn and the other elements are lowered the most. Correlations involving Cr are the least affected by the removal of the Fe and Mn influence, probably reflecting a lack of association between Cr and oxide coatings (Horsnail, Nichol, and Webb, 1969). The Cu-Co and Co-Ni correlations remain strong.

Canney and Wing (1966) found Co to be an effective pathfinder element in stream-sediment surveys for Ni-Cu-Co deposits in mafic rocks. Their data, as that of Tooms and Webb (1961), show that Co is normally more mobile in an oxidizing supergene environment than Cu or Ni, as Co is less likely to be coprecipitated with secondary hydrous iron oxides in soils. These findings, together with the high Co-Cu correlation and the fact that some of the reported Cu in the Catoctin Formation occurs in the relatively insoluble native form, suggest that cobalt may be more useful than copper as an indicator of mineralization in the Catoctin Formation.

The high positive correlation between Cr and Ni represents the close association of the two elements in bedrock. Turekian (1956) on the basis of approximately 150 analyses found Cr and Ni to be covariant in basaltic rocks. This relationship apparently persists in drainage sediments derived from metabasalts.

CONTAMINATION

No significant correlation was found between trace element concentrations and the proximity of sampling sites to two possible sources of trace element contamination: roads and inhabited buildings. Streams draining an orchard, however, contained some of the highest concentrations of copper, cobalt, and zinc. The same streams also drain the area of the old copper prospect north of Linden. The orchard is believed to be the source of some of the zinc, as zinc-bearing insecticides have been used there. The copper and cobalt may be derived from the old workings. There were no significant correlations between elements and the sizes of the areas drained by sampled streams.

DISTRIBUTION OF ELEMENTS

The locations of sample sites and corresponding values of the seven elements that were analyzed are shown in Figure 2. Concentrations of many of the elements are generally higher in samples from the southeast side of the Blue Ridge near the base of the Catoctin than in those from the northwest side (Figure 2). Mean values of all elements in 37 samples that were collected near the foot of the southeast slope were compared to the mean values of 43 samples from the base of the northwest slope. The means of all elements except iron were significantly higher in samples from the southeast slope at a probability level of .95 or greater. Mean values of chromium and nickel from the southeast side were twice as high as the corresponding mean values from the northwest side.

High concentrations of trace elements in two parts of the study area may be associated with faulting. The Front Royal fault extends across the Blue Ridge through Manassas Gap (Lukert and Nuckols, 1976). High concentrations of all elements were found along

Table 2.—Means, ranges, standard deviations, and relative standard deviations of log-transformed and untransformed concentrations.

	Untransformed				Log-transformed		
Element	Range (ppm)	Arithmetic mean (ppm)	Standard deviation (ppm)	Relative standard deviation (%)	Geometric mean (ppm)	Geometric standard deviation	Relative standard deviation of logs (%)
Copper	5-93	31.9	17.9	56	26.7	1.89	19
Zinc	17-117	72.4	22.0	30	68.6	1.42	8
Cobalt	4-62	31.5	12.7	40	28.4	1.65	15
Chromium	4-142	33.3	18.5	56	29.0	1.73	16
Nickel	3-65	21.1	10.7	50	18.5	1.72	19
Iron[1]	1.1%-10.1%	4.46%	1.56%	35	4.16%	1.49	28
Manganese	67-4110	958	619	65	804	1.85	9

[1]In percent, not ppm.

Table 3.—Simple and partial correlation coefficients based on logarithms of concentrations ($P_{.99}$ = .27)

	Zn	Co	Cr	Ni	Fe	Mn
			Simple Correlations			
Cu	.78	.91	.73	.81	.75	.75
Zn		.85	.65	.75	.75	.79
Co			.70	.78	.88	.85
Cr				.94	.47	.59
Ni					.54	.77
Fe						.65
			Iron variation removed			
Cu	.49	.78	.65	.72	–	.75
Zn		.60	.51	.61	–	.59
Co			.67	.76	–	.76
Cr				.92	–	.43
Ni					–	.64
			Manganese variation removed			
Cu	.46	.77	.54	.55	.53	–
Zn		.56	.37	.36	.51	–
Co			.45	.40	.81	–
Cr				.94	.14	–
Ni					.10	–
			Iron and manganese variations removed			
Cu	.27	.69	.56	.60	–	–
Zn		.29	.36	.37	–	–
Co			.58	.55	–	–
Cr				.94	–	–

this fault at and west of Linden. At Ashby Gap near the town of Paris several samples with high trace element concentrations were collected. As noted earlier, Luttrell (1966) reported a native copper prospect 2 miles (3 km) northwest of Paris. This occurrence and the high element concentrations may be related to the northwestward-trending fault through Ashby Gap that was mapped by Gathright and Nystrom (1974).

The four highest copper values, all over 70 ppm, were in sediment from streams draining the copper prospect in the orchard area north of Linden. The Sealoch, Ambler, and Manassas Gap mines individually were not well delineated by copper values, but the general area south of Manassas Gap in which they are located has high copper, cobalt, and zinc concentrations relative to the rest of the study area.

One sample, which was collected at the foot of the southeast slope near Trapp, contained the highest chromium and nickel concentrations, which were 142 ppm and 65 ppm respectively. The stream was

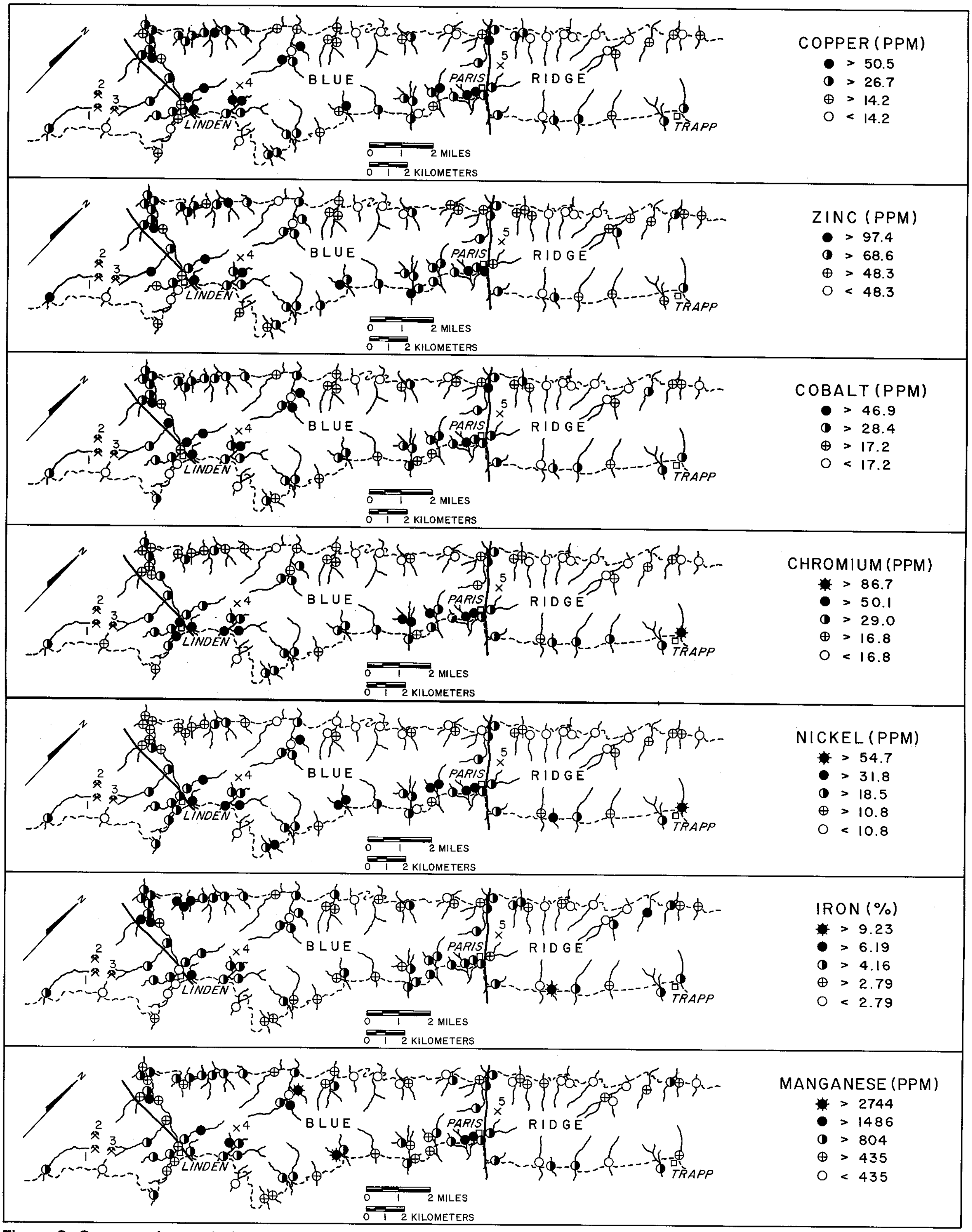

Figure 2. Copper, zinc, cobalt, chromium, nickel, iron, and manganese in stream sediments derived from the Catoctin Formation. Irregular solid lines represent streams, dashed lines show contact of the Catoctin Formation with other rock units, and heavy solid lines represent major faults; see Figure 1 for fault, mine, and propect names. The concentration ranges in parts per million (ppm) are based on intervals equal to the geometric standard deviations. The concentrations shown are from lowest to highest the geometric mean (g.m.) ÷ the geometric standard deviation (g.s.d.), g.m., g.m. X g.s.d., g.m. X [g.s.d.]^2. No values of copper, zinc, or cobalt are above g.m. X [g.s.d.]^2.

resampled at 500-foot (152-m) intervals above the original sample site. The high chromium and nickel values were repeated in two of the samples—one collected at the original sample site and the other 500 feet upstream. Bedrock samples representing the base of the Catoctin near its contact with Swift Run metasediments were collected along the stream in the anomalous area. Rock types included massive greenstone; pale-green epidosite; gray, magnetite-rich epidosite; phyllite; and jasper. X-ray diffraction and fluorescence analysis of the rocks and of heavy mineral and magnetic fractions failed to identify the source of the chromium and nickel.

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ORTHOPHOTOQUADS

Innovative pictures as viewed from an airplane of portions of the Commonwealth are available as orthophotoquads. These are black and white photographic presentations of the same areas as the 1:24,000-scale topographic maps; each depicts about 60 square miles. They show a bird's-eye view of the countryside, and they are especially useful for locating individual properties and interpreting the use of the land. When examined with the corresponding topographic map, they are the "perfect pair" for having information available on the natural and man-made features of the Commonwealth. Seventy-one are now available for eastern portions of Virginia (see back page). They can be purchased for $1.30 each ($1.25 plus $0.05 State sales tax) from the Virginia Division of Mineral Resources, Box 3667, Charlottesville, VA 22903; if unfolded copies are desired by mail, add $2.00 for orders of ten or fewer copies.

Features on the earth's surface are shown in black, shades of gray, and white. The shape, arrangement, and shade of the portrayed features assist in identifying them. Cultivated fields and pastures are usually light-gray areas bounded on some sides by straight lines. Roads appear as straight or curved lines. Streams have meandering outlines. Buildings appear as small squares or rectangles. Distances between points of interest can be measured. Tree and field areas can be computed. Deciduous trees can be differentiated from coniferous ones.

Orthophotoquads are produced as part of a joint Virginia Division of Mineral Resources-U.S. Geological Survey cooperative pilot program to determine user needs for new map products. If the corresponding topographic map is placed over the orthophotoquad so that the boundaries of each coincide and then are folded together, similar positions on each can be easily located. The map will best depict names, buildings, political boundaries, and configuration of the landscape whereas the orthophotoquad will show the positions and characteristics of individual properties. Detailed topographic maps at the scale of 1:24,000 are available for the entire State; thus, they are available for each orthophotoquad area.

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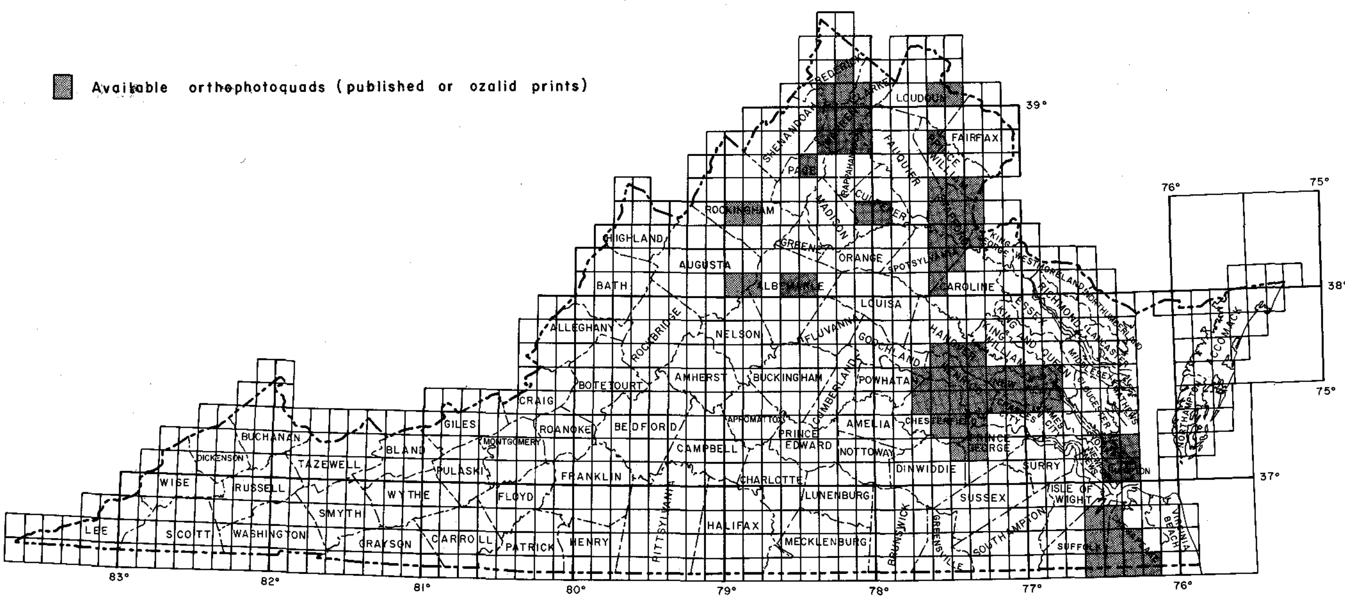

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*Culpeper West
*Deep Creek
Drewrys Bluff
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Studley
*Suffolk
Toano
Tunstall
Walkers
Waynesboro East
*Waynesboro West
West Point
*Widewater
Winchester
Yellow Tavern

NOTE: *No revised 7.5-minute topographic quadrangle maps were published from June 27, 1977 through September 15, 1977.* However, total state coverage of topographic maps is completed; index is available free. Published topographic maps for all of Virginia may be purchased for $1.25 each (plus 4 percent State sales tax for Virginia addresses) from the Virginia Division of Mineral Resources, Box 3667, Charlottesville, VA 22903.